cyanide, in common with some other substances, was unusually great. This increase of it in the urine was found to correspond with its decrease in, or more frequently its disappearance from, the saliva. This circumstance goes to prove that the salt is not formed by the saliva, but is an ingredient of the blood itself.

XIV. "On some Elementary Principles in Animal Mechanics."—No. II. By the Rev. Samuel Haughton, M.D. Dublin, D.C.L. Oxon., Fellow of Trinity College, Dublin. Received June 14, 1869.

In a former communication to the Royal Society on this subject (Proceedings, 20th June 1867), I endeavoured to establish the two following principles:—

I. *That the force of a muscle is proportional to the area of its cross section.*

II. *That the force of a muscle is proportional to the cross section of the tendon that conveys its influence to a distant point.*

The first of these principles is true under all circumstances, but the second requires to be modified somewhat in its statement. If the conditions as to friction of the tendons that convey the action of the muscles to a distant point be the same, then the force of the muscles will be proportional to the cross sections of the tendons; but if the tendons be subjected to different amounts of friction, then the areas of their cross sections will cease to be proportional to the forces of the muscles, as represented by the areas of their cross sections.

In my former paper (No. I.), I selected, in illustration of principle II., the long flexor tendons of the toes of the Rhea and other struthious birds, and showed that the cross sections of the muscles and tendons bore, approximately, a constant ratio to each other. Now, in the *Struthionidæ*, the conditions as to friction of the long flexor tendons of the toes are similar although different in each species, and hence it was easy to prove that the ratios of the cross sections of the muscles and tendons were nearly constant.

When, however, muscles and tendons, variously conditioned as to friction, are compared together, the constancy of the ratio of their cross sections disappears, and undergoes a variation depending on the friction to which both muscles and tendons are exposed.

In order to ascertain the proportion of the cross section (or force) of a muscle to the cross section (or strength) of its tendon in the human subject, I made the following observations on the right arm and hand of a well-developed male subject in the Royal College of Surgeons in Ireland, in March 1868.

I first ascertained the specific gravities of the muscles and tendons, with the following results;—

Muscles.

	Sp. gr.
Biceps humeri (*long head*)	1·050
Biceps humeri	1·054
Brachialis	1·053
Mean	1·0523

Tendons.

Scapular tendon of biceps	1·112
Radial tendon of biceps	1·119
Mean	1·1155

From these specific gravities it was easy to determine the cross section of either muscles or tendons, by weighing a known length of either one or other. In this manner the following Table was constructed:—

Cross sections of Muscles and Tendons in an Adult Human Male Subject, and Ratios of same.

Name of muscle.	Cross section of muscle, in square inches.	Cross section of tendon, in square inches.	Ratio of cross section of muscle to that of tendon.
1. Biceps humeri	0·895	0·0317	28·2
2. Palmaris longus	0·148	0·0050	26·4
3. Ext. carp. rad. longr.	0·584	0·0223	26·2
4. Ext. carp. rad. brevr.	0·405	0·0220	18·4
5. Biceps humeri (long head)	0·379	0·0212	18·0
6. Fl. poll. longus	0·228	0·0145	15·7
7. Fl. carp. rad.	0·234	0·0155	15·1
8. Ext. carp. uln.	0·212	0·0199	10·7
9. Fl. dig. subl.	0·618	0·0665	9·3
10. Fl. dig. prof.	0·768	0·0928	8·3
11. Ext. oss. met. poll.	0·223	0·0289	7·7
12. Fl. carp. uln.	0·182	0·0254	7·2

From the preceding Table, it appears that the ratio of the cross section of the muscles to that of the tendons may range from 7 to 28, or be four times greater in one case than another. We may also see in general, that the tendons exposed to the greatest amount of friction have the smallest coefficients of cross section. Thus the radial tendon of the *biceps* has a coefficient of 28·2, while the scapular tendon, which undergoes the friction of passing over the head of the humerus, has a coefficient of 18·0. Again, the *Ext. oss. met. poll.*, whose tendon winds round the radius, and has the duty imposed upon it of binding down the tendons of the radial extensors of the wrist, has the coefficient of 7·7, as compared with 26·2 and 18·4, the coefficients of the comparatively free tendons of these extensors.

As it might be objected that the relative cross sections of muscle and tendon, in a human subject that died a natural death, might be exceptional

in character, from wasting during the last illness, I determined to test the question by experiment, and accordingly selected a fine Pyrenean Mastiff for the purpose, which I killed by strychnia, and dissected immediately after death, with the following results, which were obtained, as before, by noting the specific gravities of the muscles and tendons, and by weighing a measured length of each :—

Cross sections of Muscles and Tendons in a Pyrenean Mastiff, and ratios of same.

Name of muscle.	Cross section of muscle, in square inches.	Cross section of tendon, in square inches.	Ratio of cross section of muscle to that of tendon.
1. Gastrocnemius	2·631	0·0520	50·6
2. Fl. carp. rad.	0·283	0·0059	48·0
3. Fl. dig. long.	0·195	0·0045	43·3
4. Ext. carp. rad.....	0·632	0·0160	39·5
5. Fl. carp. uln.	0·176	0·0056	31·4
6. Fl. hall. long.	0·680	0·0228	29·8
7. Biceps humeri.....	0·909	0·0449	20·2
8. Fl. dig. subl.	0·319	0·0251	12·7
9. Fl. dig. prof.	0·902	0·0830	10·9
10. Ext. carp. uln.	0·181	0·0197	9·2

These results, obtained from measurements made upon a freshly killed animal, confirm those found from observation of the human subject, and prove that the ratio of the cross section of the muscle to that of its tendon depends upon the amount of friction experienced by the latter, the coefficient being greater in proportion as the friction is less.

The following observations, made upon a Wallaby Kangaroo, confirm in a general way the preceding results :—

Cross sections of Muscles and Tendons in a Wallaby Kangaroo, and ratios of same.

Name of muscle.	Cross section of muscle, in square inches.	Cross sect ion of tendon, in sq uare inches.	Ratio of cross section of muscle to that of tendon.
1. Gastrocnemius.....	1·313	0.0356	36·9
2. Fl. long. dig.	0·354	0·0246	14·4

It appears from the preceding investigation that the cross section of a muscle does not bear a constant ratio to the cross section of its tendon, unless the friction experienced by the muscle and tendon be also constant, and that there may even be a *surplusage* of strength in the tendon beyond what is absolutely necessary to resist the combined force of the muscle and friction. This surplusage, however, cannot be supposed to be large, if the principle of *economy of material* in nature be admitted.